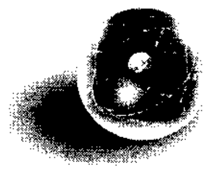

INTERNATIONAL SPACE COOPERATION: ADDRESSING CHALLENGES OF THE NEW MILLENNIUM

A U.S. PERSPECTIVE

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A EUROPEAN PERSPECTIVE

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INTERNATIONAL SPACE COOPERATION U.S. PERSPECTIVE

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As we gather here to address the challenges of the new millennium facing the global space marketplace, I must say that much has changed since this workshop last met in April 1999. Back then the outlook was one of optimism and a rapidly expanding commercial space industry. Pete Aldridge commented, during his opening remarks, that "... we have experienced a fundamental shift in the relationship between governments and the space industry, and ... the space industry will play a dominant role in space in the future." His statement was based on the premise that projections for the space industry forecast a highly profitable and strong demand for commercial space missions to support a variety of global needs.

I believe that fundamental shift in dependence has taken place, but the forecasted projections have not materialized. Thus, we have created a dilemma that governments and the space industry must wrestle with as we enter the new millennium.

Let's look at the facts. In the last two years, we have seen the dot-coms reach amazing heights in market value, and then rapidly fade away to below junk bond status. The NASDAQ is off 40% for the year, and down over 58% from its peak last spring. Technology stocks have been hammered in the process. We have seen IRRIDIUM declare bankruptcy and come within a few days of deorbiting its satellites before the U.S. government stepped in at the 11th hour and bought it out as an exclusive government system. ICO also declared bankruptcy and struggled with financing until McGraw stepped in and struck a deal to merge it with Teledesic. They have delayed the program to rearchitect it to become a data system instead of simply mobile telephony. ICO's first launch ended in failure, and they are 18 months behind its original schedule. Globalstar is just getting its business off the ground with slow customer take-up and financial difficulties. LORAL has cut off their financing and is starting to write down the loss. Recently, we've seen Skybridge announce that it is scaling back on its business plan and will depend on existing platforms to prove out their business case.

Space business mergers are continuing, with Boeing buying up Hughes Space & Communications. In Europe, ASTRIUM has been created and now represents a duopoly with ALCATEL. Murdock is posturing to buy Hughes Electronics to acquire DIRECTV and break up the rest of the company.

Satellite export controls have been shifted from the U.S. Department of Commerce to the Department of State and the licensing process has slowed to a snail's pace. The U.S. commercial satellite market share has dropped from 75 to 45% in the last 18 months. That represents over $1 billion of satellite sales going off shore. When asked why he didn't bid on the APSTAR satellite, the president of Boeing Satellite Systems said, and I quote, "It was not feasible to get an export license. It was that simple." During this same period, the U.S. launch market share went from 54% in 1998, to 38% in 1999, to 20% in 2000.

The FCC is canceling licenses for Ka-band orbit slots due to contractors not meeting their deployment schedules. The ITU is next to take the same stance. NASA has just announced that it is canceling the X-33 and X-34 next-generation RLV programs, and the latest budget for the International

Space Station has been cut back significantly, resulting in a much simplified station with only six Shuttle visits a year. And during the past two years, the industry has experienced a rash of satellite and launch failures. We've had failures with the Titan, Delta III, Sea Launch, and the H-2. We've seen computer problems hit the venerable Hughes 601s and solar cell problems strike both satellites on orbit and delay ground satellite deliveries. The recent Mars missions were likewise hit by failures.

All in all, it's not the rosy picture that was predicted just two years ago. Neither is it the vision that Arthur C. Clark wrote about in his *2001: A Space Odyssey,* where space tourism was an everyday occurrence and where computers evolved to become smarter than their inventors.

The forecast two years ago was for over 1440 satellites by 2008, and a satellite industry of $177 billion. Instead of many constellations of small LEO satellites, we are seeing satellites getting bigger and fewer. Current forecasts call for 30–50 commercial satellites per year—about one third of the previous forecast.

As a result of many of these events, and the shift in dependency that Pete Aldridge spoke of, there have been a number of investigations and studies conducted in the U.S. since 1999. Some of the ones that are of interest to our purpose are:

- The Lockheed Martin and Boeing reviews of launch failures
- The Space Launch Vehicle Broad Area Review
- The Defense Science Board studies on space superiority and air force space launch ranges
- The Inter-Agency Working Group report, Future Management and Use of the U.S. Space Launch Bases and Ranges
- The DoD-chartered study by Booze-Allen and Hamilton regarding the space industrial base
- The recently completed Commission to Assess United States National Security Space Management and Organization

I was a participant in many of these studies and have read them all. They all share a common perspective, but have reached different key findings depending on their focus. Among the more salient findings for our purpose are the following.

From the Lockheed Martin and Boeing failure investigations, we learned that engineering and not hardware was at the root cause of most of the failures. Processes and people had gotten away from the fundamental system engineering disciplines that created the past successes of the space launch business. Furthermore, cost pressures and a drive for acquisition reform on the part of the government impacted how the contractors approached the job. The checks and balances had gone out of the system and mistakes were not uncovered.

The Broad Area Review validated these findings, citing that 76% of the failures and 69% of the major anomalies reviewed were engineering related and highlighted the "need for contractor program management to provide more disciplined system engineering design and process." It further concluded that "seeking marginal cost reductions in launch, the highest risk phase of the cycle of space systems, is not likely to produce either 'better' and 'cheaper'."

The DSB Space Superiority Study recognized the growing government dependency on commercial space systems and "... endorses the efforts to fully exploit commercial space capabilities in support of national security needs ... ". With respect to international cooperation, the study recommends "... the DoD pursue international cooperative projects ... with particular emphasis on integration of foreign space capabilities into common space architectures."

The DSB Launch Ranges Study recognized that, "the government will continue to be a prominent user of the national ranges and more of an 'equal partner' with commercial users, a significant change in conditions that were projected a few years ago." But, it also concluded that, "the introduction of EELV, and the government's purchase of launch services, will change how the ranges will operate in the future."

The Inter-Agency Working Group found that although "commercial space launches now comprise about 40% of the launch manifests ... no likelihood now exists that commercial developments would support an operating regime that depended on equity markets." Accordingly, it concluded "...

that the U.S. government must ensure access to space for defense, intelligence, and critical civil sector missions and must retain ranges for test and evaluation activities of strategic importance to the United States."

The Space Industrial Base Study found that, "Although the U.S. space industrial base can support the national security community's near- and mid-term requirements, an unhealthy financial picture characterized by over-capacity and decreasing margins, inadequate innovation investment and a decline in human resources could undermine the long-term sustainability of the domestic manufacturing base." The study concluded that, "This will require a more proactive industrial base policy with DoD and the national security community."

It further went on to recognize that while

> The space industrial base has become a global enterprise ... globalization of space markets increases the exposure of U.S. firms to the consequences of technology transfer policies. Policies which retard the ability of U.S. firms to compete in the global space markets—such as lengthy licensing regimes for satellite exports and remote sensing—are reducing the opportunities for near-term economies of scale in satellite manufacturing.

And finally, the Commission to Assess United States National Security Space Management and Organization (the Rumsfeld Commission) observes that, "America's interests in space are to:

- Promote the peaceful use of space.
- Use the nation's potential in space to support U.S. domestic, economic, diplomatic and national security objectives.
- Develop and deploy the means to deter and defend against hostile acts directed at U.S. space assets and against the uses of space hostile to U.S. interest."

It further stated that "The U.S. government must work actively to make sure that the nation has the means necessary to advance its interests in space. To do so, it must direct its activities to:

- Transform U.S. military capabilities.
- Strengthen U.S. intelligence capabilities.
- Shape the international legal and regulatory environment that affects activities in space.
- Advance U.S. technological leadership related to space operations.
- Create and sustain a cadre of space professionals."

It then went on to proscribe both management and organizational changes for space, starting with a presidential focus on space and down through the government to DoD and the Air Force.

So what does all this mean to this Workshop? The implications are clear. In contrast to Arthur C. Clark's vision of space in 2001, we still have a long way to go. There are many indicators that the space economy is lagging behind the rosy forecast of just two years ago and that commercial space is far from declaring its independence from governmental influence. Although the space economy is indeed a global one, it is far from mature. It will take many more years of both national focus and international cooperation for that to happen. How fast the studies I have cited will influence that, is yet to be seen.

Our jobs for the next few days will be to put our collective experience and wisdom to work in dealing with the specific problems of global significance that are the themes of the five working groups.

In closing, I would like to acknowledge and applaud the AIAA, CEAS, IAA, and U.N. Office for Outer Space Affairs for sponsoring this Workshop. This is the sixth such Workshop that the International Activities Committee of the AIAA has sponsored, and the third that I have attended. The reports resulting from these Workshops have been widely circulated and briefed, with the last one presented at UNISPACE III—the third United Nations Conference on the Exploration and Peaceful Uses of Outer Space. But, of equal importance is the interaction that takes place among the participants of the Workshop that results in a common framework for action.

So, I challenge you to take advantage of this unique forum to engage with your colleagues and continue the good work that has gone before you. Thank you. I look forward to the dialogue and results.

INTERNATIONAL SPACE COOPERATION
A EUROPEAN PERSPECTIVE

BY ERNESTO VALLERANI
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The turn of a millennium can have a remarkable impact in the history of humankind. Consider the advent of Jesus Christ, opening in many ways a new era and introducing fundamental changes in society. Consider also the end of the first thousand years of the modern ages; it was marked in Europe by fear of the end of the world itself. Soon after, however, a renewed confidence in the future was generated all around our continent, resulting in intense activity: the population started growing, the economy gained momentum, the number and size of towns increased, and monuments and churches of remarkable style were erected as testament to the desire to build things that would survive the passage of time.

Toward the end of the second millennium a sense of insecurity and instability developed in various forms, all over a world that has become globalized. People concentrate their attention more and more on the present, having neither an interest in nor vision for the future. Compared with past centuries, we are living in a world less idealistic and much more materialistic. The concerns are practical in nature, essentially limited to our own welfare and economic aspects of life.

What are we expecting from the future? What does the new generation expect from their future? More money, more hedonistic pleasures, fewer engagements and commitments, less work ... it is by no means a challenging vision. A society without visions for its future has no future itself.

Enterprise in Space

Space enterprises have enlightened the last decades of the past century, opening new horizons to humankind. In the span of a few years, the first man-made satellite was launched, man flew in Earth's orbit, and humans reached the moon. Plans to build space outposts, reach other planets, travel around the solar system, and colonize space flourished. There was a vision, and it was exciting; the challenges were high, the expectations as well.

But with time, the idealism declined and new, more practical issues became important. Space activities were considered for the immediate services and revenues they could provide to society and not for the long-term challenges they could generate. Telecommunications, Earth observation, meteorological, and navigation satellites populated the space around our Earth offering commercially viable solutions to problems posed by the increasing needs of mankind. This is a continuing challenge for space in the new millennium: To serve the world's immediate needs. But it must not be the only challenge.

Over time, less and less attention and fewer and fewer resources have been dedicated to creating the conditions necessary to support new explorations and the exploitation of space. Space systems have developed by capitalizing on the investments of the early days instead of attracting new resources for innovative projects.

Access to Space

One issue relevant to all of us is the fundamental and vital problem of new launchers designed to ease our access to space, making it more cost effective and reliable. After the development of the Space Shuttle a quarter of a century ago, momentum was lost and nowadays this topic does not receive worldwide the attention it deserves.

We have no vision of future transportation needs, no commitments for developing innovative solutions to transportation problems, no plans for approaching and solving what remains the bottleneck of any systematic increase in space activity for the future. At this time, the problem of transportation is not approached globally, with a long-term perspective; only fragmented solutions are reached without attempting more integrated ones.

International Cooperation and the ISS

Over the years the practice of international cooperation has been largely discussed and in several cases successfully applied in space programs, but only in very few cases has it been adopted to address global issues and to provide unified responses leading to coordinated strategies. The best known attempt, at least in my eyes, is the International Space Station (ISS), in spite of all the problems associated to it.

We all acknowledge the great effort expended so far in several countries to build in orbit this international human outpost. Not withstanding the many difficulties and various controversy, the ISS elements are slowly but steadily now coming together in orbit; the most recent one, the Italian contribution—Leonardo MPLM.

The last century has left us all a relevant testimony transferable to the next generations: A permanently inhabited space base orbiting around Earth, ready for utilization. Now the challenge is to properly utilize it during the coming years and decades.

As we face the challenge of using such an outstanding laboratory complex, let us properly plan, finally, to use it for:

- Conventional R&D activities for scientific, engineering, and commercial uses
- Nonconventional uses such as advertising, recreation, education, and tourism
- New initiatives such as a new generation of space systems conceived in orbit

To achieve the best results we must develop coordinated plans for ISS utilization—this topic has been widely discussed, but the issue is still open. The problem was addressed at the third Workshop, in Frascati, in 1996. At that time recommendations were made that would lead to a centralized structure to properly support and control worldwide ISS utilization. Vox clamans in deserto, after five years we are today suffering the same situation, and the discussion still goes on. The need to create a nongovernmental organization to run the scientific and commercial utilization of ISS is debated in the United States, a discussion currently initiated in Europe as well, but without, for the time being, clear solutions.

Not yet on the horizon is the fundamental means to approach the problem of ISS utilization on an international basis, with the involvement of all the countries that have participated in its construction. This is a challenge that we reserve for the future, but when will the day come?

Long-Term Vision

Considering space activities in their totality, in spite of several worldwide projects and hundreds of satellites that are in production or are being planned, almost all of these activities respond to the specific needs of a short-term vision. An overall plan for the years to come does not seem to be of interest to anybody with the exception, most probably, of various military interests.

The space agencies around the world each have their own strategic plans, some more, some less ambitious. What is missing, in some cases even within a single agency, but surely among the various agencies, is in my opinion, a real coordination of the various plans to create a "Grand Vision" of the future of space. We have to recognize and admit that there is a need to regain confidence in the future of space and to start to invest in it again, without measuring the returns in too short a period of time.

These are the challenges of the third millennium as far as space activities are concerned:

- Conceive an integrated, global vision of future activities
- Establish a centralized plan of action
- Proceed with international implementation

Such a vision must be supported by the international community to become the vision of all, to which each country participates according to its own resources and capabilities. To be included in the Grand Vision should be going back to the moon to stay, the exploration of Mars's surface, growth of a manned space outpost in orbit, and space tourism.

Concluding Remarks

At the dawn of a new millennium we can say that the space community and more generally the high-tech community is facing three major challenges:

- The continuous provision of services useful to mankind
- The development of new, reusable transportation systems
- The appropriate utilization of the ISS

Of these three, it is particularly crucial that we first solve the basic problem of transportation into orbit. We all need to plan and develop a consistent set of reusable vehicles that will allow us easy access to and from space, to reduce transportation costs, to improve reliability and safety, and to increase, at the end, the volume of traffic.

We have already touched on, but I reiterate to further stress the issue, the urgent need to focus our attention on the establishment of a coherent vision of our future in space. This vision becomes moot if a centralized plan of action, properly prepared and agreed to as a result of the efforts of international cooperation, is not developed. What has been missing, so far, is the determination to establish joint, coordinated plans for cooperative programs. Not a collage of bits and pieces of different strategies, but one strategic vision from which to derive coherent plans.

Last comes the implementation of the agreed upon plans through international cooperation and coordination of resources, in particular the industrial ones. This is an area in which much progress is already being made through the merges and alliances that have taken place within the aerospace industry in the United States and Europe. One more valuable step would be the creation of international space companies that are capable of operating in a professional way in order to subdivide work without the duplication and redundancy of investments, consequently allowing more equitable distribution of risks. Such an arrangement would promote greater coordination of activities in order to capitalize on the specific capabilities of the various parties.

Now that these challenges have been recognized, let us get to work in creating a Grand Vision so that, when the time is right, we can accomplish whatever far-reaching goals we set for ourselves. Let us join forces and take the first steps toward our future; let us have something to pass on to the new generations.

INTERNATIONAL SPACE COOPERATION
UNITED NATIONS PERSPECTIVE

BY HANS J HAUBOLD
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FOR MAZLAN OTHMAN
Director
United Nations Office for Outer Space Affairs (UN/OOSA)

It is with much pleasure that the United Nations (U.N.) Office for Outer Space Affairs accepted the invitation to deliver this keynote address. At the outset, let me extend felicitations of the Office to the American Institute of Aeronautics and Astronautics for bringing together at this delightful location in Andalucía international experts in space-related fields, and for holding this Workshop, at which experts seek to explore ways of international cooperation in space-related issues, to address challenges of the new millennium.

In the more than 40 years that is called the space age, the development and application of space science, technology, and law have been pursued by a growing number of developing and industrialized nations. As a direct consequence, these nations have been among the first to benefit, both economically and socially, from space-related fields. Indeed, the potential for increased economic and social growth that could arise from greater utilization of space has not yet been fully realized, especially in the developing nations, even though revolutionary technologies such as satellite remote sensing, satellite meteorology, and satellite communications and their applications have gained widespread use throughout the world.

It is now desirable that—at the beginning of the new millennium—we should not only promote generally the greater use of space for peaceful purposes but also promote specifically the active participation in space benefits by the entire global community of nations.

It is precisely these challenges that lay at the core of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space, with its theme of "space benefits for humanity in the 21st century." This conference—UNISPACE III—was convened by the U.N. General Assembly and was held in July 1999 in Vienna. The UNISPACE III conference, similar to the earlier UNISPACE conferences held as far back as 1968 and 1982, provided a forum for all member states of the U.N..

At UNISPACE III, member states, U.N. agencies, intergovernmental bodies, representatives of civil society, and for the first time, private industry, recognized the need to create a practical framework for international cooperation in space-related activities and prepare for the new millennium. The UNISPACE III conference adopted the Vienna Declaration on Space and Human Development, which establishes a blueprint for the peaceful uses of outer space in the 21st century. UNISPACE III differed from previous conferences by incorporating a technical forum and a Space Generation Forum that were held parallel to intergovernmental discussions. The conclusions and proposals forwarded by these forums were discussed by government representatives and included in the Vienna Declaration, which was adopted at the close of the conference.

Some of you may recall that the outcome of the fifth AIAA Workshop served as a direct input to the efforts made at UNISPACE III to foster international cooperation in space. The conclusions and proposals of the technical forum session on the results from the fifth International Cooperation in Space Workshop, titled International Space Cooperation: Solving Global Problems, is now an integral part of the report of the UNISPACE III conference (A/CONF.184/6).

Today, I intend to highlight some of those issues identified by the report of the UNISPACE III conference that are of particular relevance to the topics of the five working groups of this Workshop.

Future Needs for Regulation of Space Traffic

As human activities in space have expanded in the past four decades, the density of near-Earth traffic has reached a level at which there may arise a significant hazard from collisions between operational spacecraft. Before this occurs there will be a need for international agreements aimed at reducing the chances of collisions between spacecraft.

The sessions of the subcommittees of the U.N. Committee on the Peaceful Uses of Outer Space prepared reports that include topics in relation to which it was considered that the negotiation of international agreements under the auspices of the U.N. would be valuable. These topics were divided into priority subjects, many of which have been dealt with in international treaties and principles, and less urgent subjects, many of which are still the subject of discussion. One of these topics is regulation of space traffic, including the proliferation of Earth-orbiting satellites, orbital management, collision avoidance, orbital debris, and orbital crowding: subjects on which detailed agreement remains to be achieved.

The subject of orbital debris has gained much importance in the work of the U.N. Committee on the Peaceful Uses of Outer Space. Its Scientific and Technical Subcommittee included the item on space debris on its agenda in 1994. Subsequently, the Subcommittee agreed that it should, inter alia, focus on understanding aspects of research related to space debris, including debris measurement techniques, mathematical modeling of the debris environment, characterizing the space debris environment, and measures to mitigate the risks of space debris. After implementing a four-year work plan, the Subcommittee adopted the draft technical report on space debris in 1999, shortly before the UNISPACE III conference. Since then, the Technical Report on Space Debris has been available as a United Nations document (A/AC.105/720) and has attracted much attention by the international space community.

During the UNISPACE III conference, as part of its technical forum, a Workshop on Space Debris was held to inform participants of the current status of the knowledge and the extent of the space debris problem, applied space debris mitigation measures, and activities related to space debris by professional societies, such as the Inter-Agency Space Debris Coordination Committee and the Scientific and Technical Subcommittee of the U.N. Committee on the Peaceful Uses of Outer Space.

An International Approach to Detecting Earth-Threatening Asteroids and Comets and Responding to the Threat They Pose

The solar system contains a large number of bodies ranging in size from planets to meteorites. Research over the last several decades has revealed that all major bodies of the solar system have suffered larger or smaller impacts of bodies ranging in size from millimeters to kilometers, the best-known example of which is the abundance of craters on the moon. Geological features on Earth show that impacts of significant size have occurred also on planet Earth. The realization that such impacts occur at long, but presently poorly known, intervals has recently caused growing concern in the public and in the press.

The hazard posed to humanity by cosmic impacts is international in character. While kilometer-sized impactors would cause important, global perturbations to the Earth's biosphere and climate, those of somewhat smaller size could also have serious international consequences, affecting densely populated coastal areas in several countries. Those well-known circumstances [and the fact that more detailed assessment of the impact hazard requires a survey and study of the near-Earth object (NEO) population, for which an effort by the international astronomical community is necessary] form the basis for a number of space entities, among them the National Aeronautics and Space Administration of the United States, the International Astronomical Union, the Spaceguard Foundation, and the European Space Agency, to focus on detection and follow-up observation of NEOs.

The recent report of the task force appointed to advise the government of the United Kingdom on research policies related to potentially hazardous NEOs gives a summary of the current situation with a welcome emphasis on the international aspects. This report has been made available to U.N. member states during the most recent session of the Scientific and Technical Subcommittee of COPUOS in February this year. The report provides a follow-up on earlier planning efforts initiated in the United States, which resulted in defining the Spaceguard System for the inventory of the population of kilometer-sized Earth-crossers, while now pushing the goals further.

As part of the technical forum of UNISPACE III, the Workshop on Near-Earth Objects reviewed the problem of possible collisions of asteroids and comets with Earth. This workshop also recommended that every effort be made to provide financial support for NEO research, both theoretical and observational, from ground and space, and especially for the encouragement of exchange and training of young astronomers in developing nations.

Global Navigation Satellite Systems

If the possibilities offered by satellite navigation were fully exploited by civil applications, the result would be better control of air, sea, and road traffic, leading to considerable savings in resources and therefore costs, both in industrialized and developing nations. The signals provided by Global Navigation Satellite Systems (GNSS) enable continuing improvements in the productivity of national and regional infrastructure such as transportation, telecommunications, oil and gas, agriculture and financial networks. Research on new applications of GNSS technology shows promise in such areas as earthquake prediction and satellite atmospheric measurements using GNSS signal occultation techniques, which may one day be an important input to weather prediction.

Currently, the main objective of developing new satellite navigation programs is to implement technologies that will ensure that data from two existing global navigation satellite systems, the United States' GPS and Russia's GLONASS, will also be available for civil use on a reliable basis and will provide the requisite precision. GPS is fully operational, consisting of 24 active satellites and active spares in orbit. GLONASS is now operating with 15 active satellites.

To improve the positioning information of the current GPS and GLONASS civil signals, the European Commission, ESA, and the European Organization for Safety of Air Navigation together have begun to implement the European Geostationary Navigation Overlay Service (EGNOS) as an initial global satellite positioning system. EGNOS is based on a regional augmentation of GPS and GLONASS and will employ navigation payloads on geostationary satellites. Europe has also initiated the development of the Galileo project, which is a second-generation independent satellite navigation system.

At UNISPACE III, as part of the technical forum, the Workshop on Global Navigation Satellite Systems was held with the objective of demonstrating how navigation and positioning technology could help solve problems of regional or global significance. Among the main conclusions of the workshop were the following: 1) Since it is universally accepted that differences in the pace of development around the world should not lead to incompatibility between elements of navigation and positioning systems, it is intended to achieve full compatibility and interoperability of regional satellite navigation systems throughout the implementation process. 2) A public–private partnership approach is recommended in Europe as the way forward for infrastructure and service development.

Space and the Public: A Critical Link

I recall from the technical forum and Space Generation Forum activities during UNISPACE III that the exploration of possible links between, on one site, space research and technology (including applications, commercialization, education) and, on the other site, public outreach (including awareness, understanding of benefits, maintaining excitement for space activities) was a particularly difficult issue to tackle. In both forums, a number of workshops addressed the involvement of the education community at all levels to inspire students, create learning opportunities, enlighten inquisitive minds, and communicate widely the content, relevancy, and excitement of space activities and discoveries to inspire and to increase understanding and the broad application of space science and technology. Space science and technology have an extraordinary potential for helping to ensure that a continuing supply of scientists, engineers, and technologists will be available to meet the needs of the new millennium. Discoveries by space missions and research programs have engaged people's imaginations, informed teachers, and excited students and the public about science and exploration.

UNISPACE III, inter alia, reviewed an initiative in the developing nations to establish and operate regional Centers for Space Science and Technology Education, affiliated with the United Nations, in Africa, Asia and the Pacific, Latin America and the Caribbean, and Western Asia. This initiative is lead by the United Nations, based on two resolutions of the U.N. General Assembly. These regional centers are based on the concept that by pooling limited material and highly qualified human resources, developing nations could have education centers, of an international-level quality, that will prepare indigenous personnel in the use of space science and technology, in particular those applications relevant to national development programs such as remote sensing and GIS, satellite meteorology, space communications and GPS, and basic space science. Such regional centers are currently in operation or under establishment in Morocco and Nigeria for Africa, India for Asia and the Pacific, Brazil and Mexico for Latin America and the Caribbean, and Jordan for Western Asia.

In a coordinated international approach, the United Nations has developed model curricula for these regional centers at a workshop that was organized and hosted by the Government of Spain in Granada, Andalucía, in 1995. These curricula in space science and technology are available as a U.N. document (A/AC.105/649) and are being implemented in the regional centers.

Contribution of Space Systems to the Implementation and Verification of International Environmental Agreements

Remote sensing technology, increasingly crucial to the understanding of Earth's climate and environmental processes, now permits the monitoring of global environmental conditions and the gathering of data that were historically unavailable. At the same time, the number of international agreements and protocols on environmental protection (treaties negotiated between nations to promote environmental protection) has grown rapidly since the 1972 Stockholm Conference on the Environment. Experts say that remote sensing of planet Earth has great potential for shaping international environmental policy.

The most recent milestone in Earth observation activity, NASA's Earth Observing System, consists of a fleet of satellites specifically designed to study global change. The flagship of the EOS satellites, Terra, was launched in December 1999. Five sensors aboard Terra collect data that provide information about how the Earth's lands, oceans, atmosphere, ice, and life function as an interdependent system.

Since Landsat, satellites have provided continuous surveillance of the Earth's surface, and the number of remote sensing instruments orbiting the Earth is continually increasing. Today, more than a dozen nations, among them developing nations, use remote sensing technologies to address environmental issues both within their own and along shared borders.

Today, multilateral environmental agreements address almost every part of the Earth's biophysical systems, and many contain provisions for monitoring, reporting, and assessing environmental data. The United Nations Framework Convention on Climate Change, adopted in 1992, provides for the stabilization of greenhouse gas concentrations in the atmosphere at levels that prevent interference with the global climate system. The Convention on Wetlands of International Importance, adopted in 1971, provides the framework for international conservation and wise use of wetlands. Other agreements address issues such as deforestation, desertification, protection of marine areas and wildlife habitat, and biological diversity.

During UNISPACE III, as part of the technical forum, a number of workshops focused on space activities for the benefit of global climate and global change, including the Workshop on Space Law in the 21st Century, organized by the International Institute of Space Law.

Concluding Remarks

Since 1999, U.N. member states have been making efforts to translate the recommendations adopted by UNISPACE III into practical programs. The Office for Outer Space Affairs, which is the secretariat of the U.N. Committee on the Peaceful Uses of Outer Space, is making every effort to assist member states in the endeavor.

In summary, I have outlined some of the issues related to a number of major trends that characterize space activities today and that will influence our efforts to solve problems of global significance. They have been discussed during UNISPACE III, and this Workshop will elaborate on them. These issues by their very nature can only be resolved through better international cooperation. Your presence today indicates your interest in making lasting contributions to these issues through greater international cooperation. On my part, on behalf of the United Nations Office for Outer Space Affairs, I thank you for your interest and efforts, and I look forward to us working together to build such a cooperation, not only during the course of this important Workshop but, hopefully, to continue that effort in the spirit of the UNISPACE III conference.

LIST OF PARTICIPANTS

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National Aeronautics and
Space Administration
Office of the Administrator
Washington, DC 20546-0001

FEB 11 1998

The Honorable William Kennard
Chairman
Federal Communications Commission
Washington, DC 20554

Dear Mr. Chairman:

Thank you for your letter of December 31, 1997. NASA is pleased to assist the Federal Communications Commission (FCC) in the matters of orbital debris, particularly those issues associated with Low Earth Orbit (LEO) satellite systems.

As you noted, in August 1995, NASA implemented NASA Management Instruction (NMI) 1700.8 (recently reissued as NASA Policy Directive (NPD) 8719.3), with the publication of NASA Safety Standard (NSS) 1740.14, "Guideline and Assessment Procedures for Limiting Orbital Debris." NPD 8719.3 states and NSS 1740.14 provides implementation guidance for NASA's policy "to employ design and operations practices that limit the generation of orbital debris, consistent with mission requirements and cost-effectiveness." Although NSS 1740.14 applies only to NASA programs, the recently drafted Federal Government orbital debris mitigation standard practices were derived from the NASA document. These draft standard practices were presented to industry at a U.S. Government-sponsored workshop that was held in Houston, Texas, January 27 to 29, 1998. This workshop was in direct response to Recommendations 2 and 3 of the 1995 Interagency Report on Orbital Debris.

I have directed NASA's orbital debris program manager, Nicholas Johnson of the Johnson Space Center, to work with Karl Kensinger of the FCC's International Bureau on all such matters of interest to the FCC. Initially, Mr. Johnson will address the issues that you raised in the Specific Technical Inquiries enclosed with your letter.

NASA looks forward to continued technical cooperation and coordination with the FCC, including development of national and international strategies, on the subject of orbital debris.

Sincerely,

Daniel S. Goldin
Administrator

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
2101 NASA Road 1
Houston, Texas 77058-3696

4 March 1998

Reply to Attn of: **N. L. Johnson, SN3**

Mr. Karl Kensinger
International Bureau
Federal Communications Commission
Room 505A
2000 M Street, NW
Washington, DC 20554

Dear Karl,

Re Mr. Kennard's 31 December request to Mr. Goldin for technical assistance on orbital debris issues related to the Orbcomm satellite constellation, please find below responses to the three identified issues.

1. State of the satellites 25 years following mission completion.

   Plans, as evidenced by the Orbcomm launch of 23 December 1997, call for Orbcomm satellites to be directly inserted into nearly circular orbits at an altitude of approximately 825 km. Since Orbcomm satellites contain essentially no orbital maneuver capability, they will begin natural orbital decay immediately. The rate of decay will be strongly dependent upon solar activity, which is now emerging from solar minimum. As solar activity increases, the Earth's atmosphere is heated, noticeably increasing the atmospheric density below 1000 km. The predictions for the severity of the 11-year solar cycle just underway (Cycle 23) suggest above average values of solar radio emissions, F10.7 (the principal factor applied to atmospheric density equations), but not record values. However, our ability to forecast solar weather is on par with terrestrial weather prognostications.

   NASA understands that Orbcomm satellites are designed for an operational lifetime of 5-8 years. Hence, 25 years after mission completion should equate to 30-33 years after launch. In November 1997 Orbital Communications Corporation provided NASA with some estimates of the orbital lifetimes of their Orbcomm satellites based on launch in January 1998. They reportedly ran 250 Monte Carlo simulations of various solar cycle scenarios using two different values of area-to-mass ratio: 1.5 m^2/41.5 kg and 2.0 m^2/41.5 kg. The variations arise from the uncertainty of the attitude of the satellite during decay. In the first case, orbital lifetimes ranged from 43 to 56 years with a most probable value of 47 years. In the second case, the orbital lifetimes ranged from 33 to 42 years with a most probable value of 36 years. For the former (worse) case, the approximate altitude of the satellites after 30-33 years in orbit was 730-740 km. Note that since atmospheric density increases exponentially with decreasing altitude, the time from 730 km to reentry is much shorter than from 825 km to 730 km.

2. What information would NASA require to complete such an analysis? What methods do NASA and the commercial satellite industry use to make such predictions?

   To verify the Orbital Communications Corporation's calculations, NASA would require relatively simple technical information about the Orbcomm satellites. Specifically, a moderately detailed diagram of the satellite with dimensions noted, its mass including rate of decrease of mass during mission lifetime due to consumption of expendables, the location of the center of mass, and information on the normal attitude of the satellite during operations and its likely attitude at mission termination would be needed. We would then use multiple existing orbital decay programs to evaluate likely decay behavior based on different solar cycle scenarios. Solar cycle predictions are available from NOAA's Space Environment Center and other scientific and academic institutions, and orbital decay programs are available from DoD and NASA Goddard in addition to NASA-JSC in-house programs.

3. What factors did NASA consider in developing its practices for operations in LEO, and in particular the practice of deorbiting with 25 years? In this regard, what factors lead NASA to identify 25 years as the relevant time period? What, if any, negative effects or risks can be anticipated from satellites that do not follow this practice, and instead deorbit at some later time? What are the methods of quantifying those effects?

   Several years ago NASA exercised its EVOLVE LEO satellite environment program to examine the effects of various orbital debris mitigation techniques. For example, the long-term (100 years or more) consequences on the rate of the satellite (spacecraft, upper stages, and debris) population of passivating spacecraft and upper stages were investigated. Similarly, different launch traffic models were also inserted to observe population influences. Since the amount of mass in LEO is directly related to the probability and severity of orbital collisions, removing mass from LEO as soon as possible after mission completion has been proposed as a means of curtailing satellite growth rates. Therefore, EVOLVE runs were made with the assumptions that no removal was performed (essentially the practice of the past 40 years) and that spacecraft and upper stages were removed within some specified time after mission completion (usually several years after launch for spacecraft, but the day of launch for upper stages). These analyses suggested that, if spacecraft and upper stages were limited to less than 25 years in LEO from mission completion, the rate of growth of the satellite population was acceptable. In other words, the growth rate did not become exponential due to the production of collisional debris. As you are aware, the 25-year recommendation was recently included in the draft U.S. Government orbital debris mitigation standard practices.

   Please note three important aspects of this previous work. First, the study did not explicitly include the new generation of LEO commercial communications networks now being considered and deployed. On the other hand, higher rates of Russian LEO launch activity were assumed than are now deemed likely. Secondly, since the earlier work, NASA has developed a better understanding of expected velocity and ballistic coefficient distributions associated with debris created in on-orbit explosions and collisions. These parameters affect the longevity of debris in orbit and, therefore, the growth of the satellite population. We are in the process of improving such distributions in the older EVOLVE model. Finally, the 25-year value was based upon the assumption that all spacecraft and upper stage operators (domestic and foreign) adopted the orbital lifetime reduction policy. The effects of non-uniform adoption were not considered. In 1998 NASA plans to conduct a sensitivity analysis of this issue with new, higher fidelity models, in particular with EVOLVE 4.0 now under development.

   Satellites and upper stages which are not removed from LEO within 25 years of mission completion obviously increase the probability that they will be involved in accidental collisions which would likely result in the creation of large numbers of debris, which in turn could threaten other resident space objects. Since the orbital decay process is an exponential one, longer lifetimes mean prolonged stays at the higher altitudes where the space object spatial density is higher, leading to a higher likelihood of collision. The magnitude of the effect of deviation from the 25-year guideline must be evaluated on a case-by-case basis.

   In the case of Orbcomm, I note that deployments to altitudes of 825 km or more have already begun, in particular with the missions of 23 Dec 97 and 10 Feb 98. Under current NASA policies, existing vehicles need not be subjected to redesigns to meet orbital debris mitigation guidelines if such redesigns are not cost-effective or adversely affect mission objectives. The Orbcomm design meets most of NASA's guidelines, and the slightly longer-than-desired projected orbital lifetime might be viewed as an acceptable variance for an established system.

I hope the above remarks provide better insight into the sometimes complex issues associated with orbital debris and the growth of the satellite population. NASA remains available to assist the FCC on these and related topics and would like to extend to you and your colleagues an open invitation to visit JSC for further discussions.

Sincerely,

Nicholas L. Johnson

Nicholas L. Johnson
Chief Scientist for Orbital Debris